CLAIMS

Therefore, having thus described the invention, at least the following is claimed:

1. An apparatus for determining *in situ* pore fluid and soil properties, the apparatus comprising:

a penetrating tip member configured to penetrate the soil; and

an attachment module coupled to the penetrating tip member, the attachment module including at least one mandrel, the at least one mandrel including at least one piezo sensor,

wherein the at least one piezo sensor obtains an *in situ* measurement of pore pressure at a location corresponding proximal to the at least one mandrel on the attachment module.

2. The apparatus of claim 1, wherein the attachment module further comprises a hollow inner chamber for containing data and power components.

3. The apparatus of claim 1, wherein the penetrating tip member further comprises a conventional cone penetration testing (CPT) module.

4. The apparatus of claim 1, wherein the attachment module further comprises at least one load cell, the load cell being coupled in sequence to the mandrel,

wherein the at least one load cell obtains an *in situ* measurement of interface strength at a depth that proximal to the location of the at least one load cell.

5. The apparatus of claim 4, wherein the at least one piezo sensor is coupled adjacent to at least one load cell, the at least one piezo sensor being isolated to measure the pore fluid pressure generated for the at least one load cell, wherein a friction sleeve associated with the at least one load cell induces an internal shearing of the soil which enables the piezo sensor to measure pore fluid pressure.

6. The apparatus of claim 4, wherein the at least one load cell further comprises a friction sleeve configured with a surface texture, where the surface texture has a corresponding surface roughness value;

wherein each of the surface textures for select friction sleeves is configured to induce internal shearing of the soil as the attachment module penetrates the soil and to be self-cleaning, such that soil particles do not adhere to a surface of the friction sleeve.

7. The apparatus of claim 6, further comprising a vertical arrangement of the friction sleeves in ascending order according to increasing roughness of the surface texture, such that the least rough friction sleeve is placed closest to the penetrating tip member and the roughest friction sleeve is placed furthest away from the penetrating tip member.

8. The apparatus of claim 1, wherein the at least one piezo sensor produces a signal at a corresponding depth in a single sounding, and the signals correspond to individual *in situ* measurements of pore fluid pressure at the corresponding depth.

9. The apparatus of claim 1, wherein pore fluid pressure measurements from the attachment module are transmitted to a data acquisition system.

10. The apparatus of claim 6, wherein the friction sleeves have an average surface roughness of approximately 0.05 to approximately 250 μm.

11. The apparatus of claim 6, wherein each of the friction sleeves comprises a surface texture that is characterized by geometric parameters, including height, diagonal spacing, penetration angle, and width.

12. The apparatus of claim 11, wherein the geometric parameters of each of the surface textures comprise height variations from approximately 0.25 mm to approximately 2.0 mm, diagonal spacing from approximately 4.6 mm to approximately 12.5 mm, and penetration angles from approximately 30 degrees to approximately 120 degrees.

13. The apparatus of claim 3, further comprising a data acquisition system, the data acquisition system comprises:

means for measuring penetration depth of the penetrating tip member and the attachment module;

means for obtaining penetrating tip member measurement values;

means for measuring verticality of the penetrating tip member; and

means for obtaining pore fluid pressure values at each measurement increment on each piezo sensor located in the mandrel; and

wherein the data acquisition system enables contemporaneous review of pore fluid pressure data.

14. The apparatus of claim 13, wherein the measurement data from each of the means for measuring is converted to digital signals, multiplexed, and then relayed to the data acquisition system.

15. A method of determining *in situ* pore fluid and soil properties, the method comprising the steps of:

positioning a penetrating tip member so as to penetrate into the soil at a particular subsurface area;

positioning an attachment module in a predetermined relationship to the penetrating tip member to form a penetrometer;

forcing the penetrometer into the soil beginning with the penetrating tip member; and

collecting attachment module measurements from at least one piezo sensor coupled to at least one mandrel,

wherein the piezo sensor obtains an *in situ* measurement of pore fluid pressure at a depth that corresponds to the location of the at least one mandrel.

16. The method of claim 15, wherein collecting attachment module measurements is performed by at least one individual load cell, the load cell including a friction sleeve that measures an interface resistance, the interface resistance corresponding to interface strength.

17. The method of claim 15, wherein collecting attachment module measurements from a plurality of load cells comprises providing each of the load cells a corresponding plurality of mandrels and friction sleeves, the plurality of friction sleeves being configured to be removable, such that the arrangement of the friction sleeves along the attachment module portion of the penetrometer may be reconfigured into different order arrangements for measuring corresponding interface resistances of the friction sleeves.

18. The method of claim 16, wherein collecting attachment module measurements from a plurality of load cells comprises each load cell with a friction sleeve configured with a surface texture, the surface texture of select friction sleeves being configured with a diamond-shaped pattern so as to induce internal shearing of the soil around the penetrometer as the penetrometer is penetrated into the soil.

19. The method of claim 16, wherein collecting attachment module measurements from a plurality of load cells comprises arranging a plurality of friction sleeves, wherein the friction sleeves are arranged in ascending order of vertically according to increasing roughness of the surface texture, such that the least rough friction sleeve is placed closest to the penetrating tip member and the roughest friction sleeve is placed furthest away from the penetrating tip member.

20. The method of claim 15, further including the steps of:

measuring penetration depth of the penetrometer;

measuring penetration tip member values;

measuring verticality of the penetrating tip member, where the penetration depth, penetration tip member values, and verticality measurements comprise the drive tip measurements; and

measuring pore fluid pressure at each measurement increment on each piezo sensors located in the mandrel.

21. The method of claim 20, further comprising converting analog measurement data from each of the measurements to digital signals, multiplexing, and then relaying the multiplexed data to the data acquisition system.

22. The method of claim 16, further comprising isolating the piezo sensor to measure the pore fluid pressure generated for each load cell, wherein the friction sleeve of each load cell induces an internal shearing of the soil which enables the piezo sensor to measure the pore fluid pressure induced by each friction sleeve of the individual load cells at a particular subsurface.

23. The method of claim 15, further comprising collecting penetrating tip measurements.